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Lessons in technology and science strategy from the Soviet experience:

A review of 'What Have We Learned About Science and Technology from the Russian Experience?' – Loren R Graham (Stanford University Press, 1998)

By Dapo Ladimeji

This is a very important book for a variety of reasons, and it raises issues that anyone interested in the future of Africa or the Diaspora must address. Anyone who wishes to ask questions such as: 'can one impose a successful forced march on Africa to bring Africa into the 21st Century? What price will be paid? What causal role does democracy and human rights play in economic and technological development? What are the pre-conditions to successful introduction of modern scientific technology and culture? What are the risks and the key factors for success?' must confront the issues raised by this book.

It is written by a distinguished American scholar, who has a thorough knowledge of Russian science. His humanity and generosity of spirit shines through the work. However this does not mean that his theories should be accepted uncritically. A critical exposition of his theory will illustrate important pre-conceptions in contemporary thinking.

His first chapter 'Is science a social construction?' focuses on two issues – the theory of social constructivism and the impact of the Lysenko crisis. Social constructivism is a relatively recent development in history and sociology of science. The older Mertonian school of sociology of science had focussed on reward systems and norms but treated 'knowledge' itself as a sacred black box. In the history of science there were the 'internalists' who argued that the development of science was the result of 'pure' debate of ideas and facts and the 'externalists' who took into consideration wider social and economic issues. Michel Foucault spent time elaborating the intertwining of complex social, cultural and economic factors in the development path of ideas.

Graham identifies three positions – the internalists who deny the legitimacy of social influences, the extreme social constructivists who reduce all knowledge to 'mere' social construct and a middle path that accepts there is both important and beneficial social influences on the production of knowledge, but that there is a place for a residual concept of 'reality' or brute facts that even social constructs need to take into consideration.

Graham then applies this model to the Lysenko case. He argues that the social and political influences that led to its rise are easily identified while it was the final intrusion of 'brute facts' that brought the whole system down. In this particular case, the social and political factors were supporting a bad scientific theory that was inadequate from inception.

However, he argues that not all social and political factors produce negative influences on science. He then identifies Lev Vygotsky's contribution to psychology and language as a development of Marxist ideas. He also identifies significant

contributions to astrophysics that were influenced by Marxism. The Marxist and State supported theory of dialectical materialism has led to some positive scientific developments. In Graham's view one must be as sophisticated in one's evaluation of the impact of Marxism on science as one would be of the impact of Christianity or Islam.

In the second chapter 'Are Science and Technology Westernising Influences?' Graham states: 'The thesis of this chapter is that science and technology have acted powerfully as moderating influences, as forces pulling Russia toward the West, as factors reducing the differences between Russia and the West'. What Graham is arguing is that the Soviet view of their own 'exceptionalism' – that things in the Soviet Union will be quite different than anything before or elsewhere – is undermined by the progress and development of science which by its universalism shows that the Soviet's were like the West.

Graham argues that the need for co-operation over arms control, the wish of the Soviets for technology exchanges in order to catch up with the West led to joint-ventures with Western firms. Ecological disasters generated action groups and whistle blowers on a pattern similar to that in the West.

Graham's position on the influence of technology is in fact a subtle one. He argues that a whole range of factors, fear, greed, xenophobia, conservatism all influence with different weights at different times the attitude of Russians to the West, but that the effect of technology is consistently to bring Russia closer to the West and to undermine claims to exceptionalism.

Graham then, in Chapter 3, addresses the issue 'How Robust is science under stress?' His intriguing question is: which is more important to science, money or freedom? He shows that during the period of greatest repression Soviets produced some of their greatest scientific breakthroughs. Up and until the 1970's the Soviet Union was rated at the forefront of most fields of scientific study. However after the collapse of the Soviet Union in early 1990's and the withdrawal of most of the state funding the quality and quantity of Russian scientific endeavour collapsed. That is to say lack of funding achieved almost instantaneously what years of Stalinist repression failed to achieve.

His argument, which again is quite subtle, is that though the very great funding of science was crucial to its development, political freedom was required to gain a better return on investment. 'The Russian examples shows that, in extreme cases at least, money is more important for science than freedom, but of course the best science will be done when both freedom and money are present.' (p.73)

If the return on investment in Soviet science became so appallingly low a further question arises: Why didn't the scientists reform themselves? This is a question Graham addresses in his next chapter 'How willing are scientists to reform their own institutions?'

The enormous Soviet state investment in science led to great prestige and perks of office for scientists and the creation of an enormous bureaucracy. In his words: "Looking over this Soviet system of research, we can isolate some of its central features: it was large in numbers of researchers, highly centralized in organization,

dominated by powerful leaders. Fundamental researchers had little contact with applied researchers, and both fundamental and applied researchers had relatively little contact with students, especially undergraduates. Funding of research within this system was not dispersed on the basis of competitive applications by individual researchers, but by block funding of institutes by the central Academy presidium, which got its money from the government. This method of funding gave members of the presidium and institute of directors great influence, the power of the purse ... The system of Soviet research emphasised quantity over quality, seniority over creativity, military security over domestic welfare, and orthodoxy over freedom. The scientists who were in charge of this system had great authority, little accountability, few teaching responsibilities, and enormous personal privileges. No wonder they liked it.'

His view of the consequences of this feather bedded bureaucracy can be summed up: 'When one considers that the mature Soviet Union possessed the world's largest scientific establishment, one must conclude that the output of that system was disappointingly meagre.'

In Graham's view the recognition of the need for reform and possibly the will to effect it, came at a time when there were no funds to smooth the path or to properly establish a new structure.

Graham's next concern relates one suspects more to US concerns than Russian and is entitled 'Who should control technology?' The story, as told by Graham, is of both Russia and US at the turn of the 20th century having a blind faith in mega projects led by technical specialists. These mega projects were show pieces of industrialization such as TVA etc. In Graham's words: 'During the twentieth century, the attitudes both of the larger public and of technical specialists in the Western world to such megaprojects changed in a fundamental and irreversible way. In the early part of this century, the view was widespread that such projects should be entirely planned and executed by technical specialists. Industrialization, construction, and modernization were activities about which specialists – industrial managers, engineers, economists, government planners – were thought to possess superior knowledge. This technocratic ideology was widespread through all industrialized nations, and was particularly strong in the United States, where the idea of progress was often linked to the advance of technology. In the United States at the end of the nineteenth and beginning of the twentieth centuries, the doctrine of progressivism included the belief that good public works projects could be built and operated efficiently only if technology was divorced from politics and placed under the control of engineers' (p99). 'But just as the United States was a place where the progressive idea that engineers might be excellent social planners achieved early strength, it was also the place where the technocratic dream faltered most dramatically. The loss of faith in technical experts by Americans was a long process, which I do not have space here to describe in detail, but perhaps the most traumatic moment in that history was the 'Freeway Revolt' of the late 1960's and early 1970's, when the interstate highway construction project – the largest public works project in history – was brought to a halt in a number of cities, including San Francisco, New Orleans, Boston, Philadelphia, and San Antonio. The public had been alienated by the high-handedness of the engineers, who were ramming multilane highways through city neighbourhoods, uprooting thousands of citizens, and destroying entire communities. The rallying cry of the rebels was that the public had been almost completely excluded from the planning process. In other words, the

motto of progressivism at the beginning of the century was turned on its head: the point was not to exclude politics from technical planning but to make it an integral part of that planning.’

Graham’s argument is that the Soviet Union was ossified in the past: ‘Against the background of this evolution of attitudes in the United States toward the planning of megaprojects, the history of Soviet industrialization is particularly interesting. In the Soviet Union, the tendency toward the technocratic planning of megaprojects that had once been so characteristic of the United States continued to develop into a particularly monstrous form, which totally disregarded the public. American-style affection for megaprojects planned by engineers was wedded in the USSR to the scientism of Marxism and the authoritarianism endemic in Russian politics to form an almost unstoppable oligarchy of technically trained industrial planners. Only the demise of the Soviet Union could halt this monstrous technocracy. Even now, Soviet-style technocracy lives on in China, where the Three Gorges Hydroelectric Project is being pushed in the same way that Soviet ventures once were – that is, by the total exclusion of the public. Indeed, the leading exponent of the Three Gorges Project, Premier Li Peng, is a graduate of a Soviet engineering institute of the 1950’s, and he still espouses an ideology typical of Soviet industrial planners.’

Graham identifies Pal’chinskii, an early Soviet ‘dissident’, as someone who clearly saw the dangers of technically planned megaprojects where the social costs of dislocation and uprooted lives is left out of the cost-benefit equation. Graham contrasts the centrally planned autocratic and technically controlled Soviet megaproject with politically correct US Central Artery project that extensively involved local participation etc.

After a kaleidoscopic survey, Graham feels in a position to draw some conclusions: ‘Science is a social construction in the sense that scientists, members of society, make it, and they are inevitably influenced by social factors in the process. Contrary to the views of many natural scientists, the influence of social factors extends to the core of science itself, the theories of explanation around which the scientist of a field frequently unite. But natural science deals with objective reality to a much higher degree than the humanities, and therefore empirical evidence is often much more influential. The leash that ties scientific theories to reality is far longer and slacker than most people know, but it does exist.’ (p.127)

Graham concludes that the knowledge industry in a modern society is both mammoth in size and importance, and robust against maltreatment. ‘The knowledge industry in modern societies is no longer a minor affair run by an intellectual elite, an activity that might be considered by pragmatic leaders as expendable; it is a mammoth enterprise on a par with heavy industry, and just as necessary to the country in which it is situated. By the late 1980’s there were more employees in ‘science and science services’ in the Soviet Union than there were in the fuel, energy, and metallurgical industries combined.’ (p.129) ‘Today, every industrial society needs science and will find a way to support it, even if that same society frequently abuses science. The Soviet Union politically repressed science atrociously while simultaneously supporting it financially more fulsomely, relative to its resources, than any other country in history. The sobering conclusion that we must draw, in terms of scientific results, is that the support counted for more than the repression. Under the Stalinist

system, the Soviet Union became a major scientific nation, developing nuclear weapons and other sophisticated armaments and sending the first artificial satellites into orbit. And its achievements were not only in strategic areas. In abstract and fundamental fields, such as mathematics and theoretical physics, the Soviet Union became a world leader.' (p.130) 'The robustness of science, its ability to survive and even prosper in the most inhospitable environments, leads us eventually to a clearer justification for democracy and human rights. Westerners have often in the past maintained that freedom and human rights are necessary for a flourishing and creative economy. This message is now being propagated by the United States throughout the world, with considerable success. The Soviet experience shows that there is, indeed, a positive correlation between freedom, on the one hand, and a prosperous economy and a creative culture, on the other. Soviet culture and science were not as productive as they should have been, considering the enormous resources they consumed; the lack of freedom and an open market were certainly important causes of this failure. But Soviet science was sufficiently successful that we can see the dangers of the utilitarian argument, the belief that democracy and human rights are justified by the fruits they produce.' (p.131) Graham concludes with strange argument: 'Democracy and human rights are more important than science and should take priority over it.' This argument is curious as it comes out of nowhere. (The issue for the Soviet Union was survival of the nation under military threat from the West in the form first of Hitler's storm troopers then of the US and NATO and the theory of containment. Military survival required rapid scientific development and without military survival human rights as a conquered nation would be a worthless demand.)

To the question of reform, Graham concludes that scientists as a community are as subject to interest group behaviour as any other section of society. As to controlling technology, Graham concludes that 'The example of the Soviet Union shows that technology, especially the megaprojects that reshape the lives of entire communities, is far too important to leave to the technical specialists.'

One view of this text, given the context of the collapse of the Soviet Union, is that it is an extended exercise in *schadenfreude*.

As was stated at the beginning we cannot be uncritical about these views. What then can one say about Graham's theses after critical review? Is Graham's portrayal of the social constructivism adequate? As an undergraduate and later postgraduate student at Cambridge University in the early 1970's I published articles along this line. At that time often the politest response was that, despite my being a philosophy graduate, my grasp of logic was inadequate. Time has passed. But on reviewing Graham's account of the issues I suspect not enough time has passed .

Social constructivists argue that science is subject to the influence of the society in which it is practiced. An extreme form of this position might state that science is determined by the social context – or more formally, science becomes an epiphenomena to underlying social forces. This extreme form gives a low or negligible role to empirical reality or the force of circumstances. By contrasting this straw man against the old-fashioned internalist position Graham places the default position as a middle ground between two extremes – an old-fashioned if harmless oratorical/polemical tactic. A rigorous analysis gives rise however to some serious objections to Graham's analysis.

If one takes the mathematical truth that for any set of numbers/points (facts) an infinite series of formulae/lines (theories) can be found that maps/fits (conforms) to it, one could show that in principle social pressures could add to (or suppress from) a primary set of numbers/points (facts) A_1 , another set of numbers/points (facts) A_2 , whose existence is solely to bolster the status quo. Therefore a new theory, T_1 , could be developed that encompassed A_1 and A_2 (either $A_1 + A_2$, or $A_1 - A_2$), but whose choice, out of the infinite set of possibilities, is largely determined by the social structure/context. This model could then be expanded with a Lakatosian gloss to the effect that no new set of numbers/points (facts) could overwhelm any theory as a revision of that theory to T_2 could incorporate the new numbers/points (facts). Such arguments would appear irrefutable both at the level of mathematics and history and philosophy of science.

A rigorous analysis of the social constructivist position shows the inadequacy of Graham's review of the Lysenko period. Lysenko adopted a neo-Lamarckian theory of the inheritance of acquired characteristics. To say that Lysenkoism was refuted by the facts is clearly inadequate analysis. All theories can adapt and evolve with new facts – and therefore the issue becomes: why did Lysenkoism fail to adapt and absorb new information? It was clearly failing to take into account new information available domestically before it failed to take into account information from abroad. A fairly similar process of ignoring the evidence took place in the arena of racist science in the US and Europe in the late 19th and early 20th Century. However modern day racist science has sought to adapt to each refutation. What caused the change? One suggestion could be that while racist science had state support in the West it did not need the 'support' of the facts. However once it lost the state support, it needed to adapt to more facts in order to achieve some sort of credibility/persuasiveness. Lysenkoism by attaching itself to its political patron became a whipping boy for the patron and no good scientist would 'develop' it as that would amount to assisting the unpopular patron. Modern day neo-Lamarckianism shows that it could have been developed, adapted to new facts.

One of Graham's major arguments relates to the effect of democracy on the productivity of science, Soviet exceptionalism and on the political culture. Graham argues that a lack of democracy led to a stifling of creativity and thereby a reduction in the quantity and quality of output. However what he in fact shows is that the centralisation of administrative power in the hands of a small clique with no separation of powers could lead to a failure of innovation. These sets of facts show no conclusion about democracy. If he crossed the river and spoke to his Business School colleagues, the business theorists would be able to show that similar circumstances can and do occur in multinational corporations with surprisingly similar results. The democratic environment being irrelevant to the issue. If what we have is a failure of organizational design then clearly the matter could have been rectified under the old regime. This raises a more interesting question – given a clear failure of organisational design why could not the Soviet system reform itself?

Under capitalism serious organizational failure leads to unacceptable financial performance and swift remedial action by the capital markets. But even under capitalist democracy serious failure that is at the heart of policy can be sustained in the face of extraordinary costs – such as the US involvement in Viet Nam. Where the

US was committed to a programme in Viet Nam that was patently failing, acceptance of that failure was not politically viable and therefore even greater commitments were made. Nixon increased the bombing as evidence of the failure grew and grew. Eventually the ultimate constraints of the political process and the international capital markets brought the recognition of the failure of the programme to the political agenda, shortly followed by the military collapse on the ground. Both political systems were capable of sustaining severe loss-making programmes if they were at the ideological core. Democracy was not the issue. Could it be that the brightest scientists no longer believed the Soviet nation to be in peril and were not motivated to reform the situation hoping for more radical change?

What are we to make of the claim that technology tended to undermine Soviet exceptionalism? By forcing the Soviets to adopt Western practices technology taught them that they were no different from the West. Firstly, national exceptionalism is not unique to Russia and can be found in the UK and the US etc. In fact when Japanese productivity began to outstrip the US many commentators complained that this must be the result of unfair trade practices. It was the turn of economists to point out that US 'exceptionalism' – that the US had a God given right to be the number one country - had no factual foundation. England taught its children that it was 'unique' as the birthplace of parliamentary democracy and of industrial capitalism. Western 'exceptionalism' was itself a state sponsored myth. In the 'official' version of the history of science when I was at Cambridge, science was something uniquely developed by Western Europe, dating from Copernicus' discovery that the Earth went round the Sun. This myth, for myth it was, was known to be false at the time. Neither Copernicus nor Newton believed they were the first to discover that the Earth went round the Sun. Newton correctly guessed that the ancient Egyptians knew this. More to the point, European science grew out of Arab science but nowhere was this mentioned in the curriculum. International trade of any kind would tend to have the effect of drawing nations closer together. If one took Graham's arguments literally one would have to conclude that the extensive industrial /scientific espionage conducted by the Soviet Union was an admirably Westernizing influence!

One fundamental premise of Graham's views, and not unique to Professor Graham, appears to be that science and technology are in themselves fundamental forces towards democracy. But science was carried on effectively by Nazi Germany and Apartheid South Africa. More to the point, given that the West used its technological superiority to invade, dominate, enslave (and occasionally wipe out) many of the populations of the world, these assumptions are breathtaking in their disregard of the facts. The fate of the American Indians, of the Tasmanians, is the opposite of living testimony to the democratic potential of technology.

However the two greatest weaknesses of Graham's analysis lie elsewhere. His claim that the Soviets had more scientists than anyone else may be subject to cautious scepticism. The US often claimed that the Soviet Union had a better funded army etc and these claims were often shown to be dubious or downright false, and failed to count like-for-like. One would suggest that the honorific status of 'engineer' and 'scientist' would tend to inflate these numbers. But a more fundamental flaw arises from the change in the capital/labour ratio for Big Science. During the 1970's there was the rise of Big Science where the capital equipment dwarfed the human input in

costs. The capital costs became so high that European countries had to pool resources to build the facilities e.g. CERN.

Where would this leave the Soviet Union? In its heyday its competitive advantage was the quantity, quality and low cost of its skilled human scientists. But when science becomes Big Science large staffs may no longer be relevant. 10 scientists and a billion dollars of equipment may produce great results where 10,000 scientists and 1 million dollars of equipment get nowhere. A shift in the capital/labour ratio of science would doom the Soviets to a back seat. All the references to centralisation, to lack of accountability etc being irrelevant. Graham compares the Soviet Union to the US on indices of manpower. He is silent on indices of capital expenditure.

This shift in capital/labour ratio for Big Science was a golden opportunity for the Soviets to release manpower from the industrial/military complex into producing goods for the domestic and export markets. This would have raised the living standards of the citizens while earning the foreign exchange required for investing in Big Science. Such a move would have shored up the political foundations/ support for the regime while increasing its military capacity. It was a missed opportunity that appears to have proven fatal.

In its own way Graham's analysis is itself highly 'internalistic' in that it focuses only on the internal social forces as explanatory data. If one places the global context back into the story we may be able to shed light on an aspect that Graham does not address. The Soviet system of science worked well at one point and then began to fail while the negative forces – the formal repression actually declined. If democracy and liberalisation were positive forces then the scientific endeavour should have improved with liberalism not declined. Consider another explanatory candidate: during the War (European War 2) the scientists shared the spirit of national emergency that overrode all other issues.

Some Soviet populations at the start of the war saw the arriving German armies as liberators from the hated communist regime only to rapidly discover that the German armies were intent on the genocide of the Russian people. The genocide attempt on the Jews has deflected attention from the fact that Hitler's Germany intended the genocide of the Russian people. The scale of slaughter envisioned here is staggering. In numbers the 6 million Jews pales before the population of the Soviet Union. The German people democratically elected Hitler even if he later abolished the constitution. What reason would the Soviets have to believe that any other democratically elected government would not be capable of genocidal assault on the Soviet Union? One also has to take into account the psychological and cultural impact on a country of being subject to genocidal attack. If one looks at the long-term impact on the Jews of the Shoah and then bears in mind that 20 million Soviets died in the war, then some appreciation of the psychological damage/ distrust in the Soviet Union can arise.

Before and after the War (European War 2), the Soviets were faced with the constant threat of external invasion; first from the Western supported White Russians and then from the West under the theory of 'containment'. This created 'war conditions' within the Soviet Union. What is the relevance of this? Even under the formal theory of

democracy 'war conditions' allow for the abrogation of human rights. When the era of 'peaceful co-existence' was announced then one of the unexpected consequences would be the end of 'war conditions'. On this scenario the era of peaceful co-existence would lead to increased dissidence on the one hand but also an unwillingness of the great scientist to devote themselves to the state's objectives. This view would reconcile the facts – a willingness to produce great science under conditions of great deprivation, even with one's relations being unjustly killed. This willingness will be evidence of a devotion to the Nation not to the regime. The key factors would appear to be a clear and apparent national emergency (in terms of the US constitution ' a clear and present danger') and a strong consensus about the means of dealing with it. For scientists the consensus was the need to catch up or exceed the West in science and technology to survive. It is well known that under 'war conditions' the rate of technical and scientific progress can increase remarkably. The phrase 'necessity is the mother of invention' comes to mind. It is also known that at the level of genetics if a population is put under extreme stress the rate of mutations increase. Once the era of peaceful co-existence arrives the consensus collapses.

One possible conclusion from this is that the Churchillian Iron Curtain and the practice of aggressive 'containment' by creating 'war conditions' inside the Soviet Union increased rather than reduced the threat to the West. The Cold War may well have been a colossal waste of resources both human and material even from the point of view of the West. With 'war conditions' removed from the Soviet Union the motivation of scientists and the rate of technical progress would collapse as concerns for living conditions and human rights would increase. A similar mistake would appear to govern US responses to Iraq.

Before we investigate the lessons to be learned for Africa we should consider the social conditions for the production of this book i.e. to be reflexive about Professor Graham and his place and time. Professor Graham was a student in the 60's, a period of student protests, of distrust of big corporations and central governments and in time when considerable focus was being given to local communities and their rights. Such concerns appear to permeate this work.

Also the US at that time and even more so now was a promoter of 'democracy'. This crusade for the spread of democracy may be just as much a cloak for other less noble interests as the crusade for the spread of Christianity. Clearly the United States, nominally a secular state, is more comfortable with the flag of democracy than the symbols of religious orthodoxy. A relevant example may illustrate my point. There are well-attested reports of secret discussions between Jeffrey Sachs, the Harvard economist, and the then US President and his advisers. These suggest that the main objective of Sach's advice to the Soviet Union on reforming/restructuring the economy was not so much to ensure a smooth transition to a free market but to rapidly and irreversibly destroy the communist system so that there should be no chance of a return. It was the Russian people who paid the price for this deceit – and today the unmanaged free market with its gangsters and rip-off artists is largely discredited as a result.

One of the structural weaknesses of present day democracy is its susceptibility to financial intrigue. From France to the UK, from Kohl's Germany to Nixon's USA, there is a repeated tale. The CIA used this weakness to assist in the manipulation of

elections after European War 2 to prevent Communists winning elections. But other secret services and interested parties realized that this technique applied equally to the US.

A further issue for the 'democracy' debate are the 'atom spies'. The Manhattan Project brought together many of the best scientists from all over the non-Nazi world, joined by a shared commitment to defeat Hitler. However that consensus did not extend to making the US the sole owner of such terrible weapons. It was fear of US world domination and lack of consensus around destroying the erst-while 'ally' who shed the most blood in the fight against Hitler, which led to the atom spies – the passing of nuclear secrets to the Russians. Similar concerns emerge in Europe to-day with regard to the US proposed anti-missile defence system.

Finally we should look at the question: what role does democracy play in economic development? Obviously to hear that democracy and human rights come above economic development on the one hand and help speed up economic development on the other, from a country whose early period capital accumulation came from slavery lacks credibility. Periods of fast growth in S Korea, Taiwan, Thailand and China have occurred when the level of democracy has been low.

In a reflexive mood we can also ask: can we explain the selection of issues (i.e. which topics were addressed and which passed over) in Graham's analysis by looking at his time and place. If we were to view this book as part of an extended *domestic polemic* then matters fall into place. By characterizing as old-fashioned Soviet ideas certain widely held views about the role of technocrats Graham goes a long way to thoroughly discrediting those ideas in the US. By emphasising the crucial importance of funding for Big Science at a time when colossal funding for Mars missions and similar are on the political agenda he gives support for those interests. 'War conditions' and 'national emergencies' are far from the domestic political agenda of the present day US so those issues can be set aside.

The present day issue for US mega projects such as the Mars mission is: how does one get political approval for colossal funding for such an elitist project at the same time as welfare spending is being cut back? Much use is made of the 'Everest defence': When asked why he climbed Mt Everest Edmund Hilary is reported to have said 'Because it is there'. When comparing US and Soviet mega projects Graham considers the US Central Artery proposal. Had he considered the Manhattan Project, the race to the Moon or the proposed Mars mission it is not clear that any great differences between the Soviet and US models would exist. To point to similarities between US and Soviet mega space projects would tend to discredit the US project.

LESSONS FOR AFRICA

Even though we have found numerous areas to challenge we have a lot to be grateful to Professor Graham for. His clear illumination of some important aspect of Soviet history and his empathetic and sympathetic rendering of the Soviet dilemma is a real contribution. His understanding of and, one suspects, fondness for the Soviet people shine through every page.

What does the Soviet experience suggest for Africa? I would summarize these lessons below:

1. A sense of emergency, of continental emergency, and a consensus of the way forward is the precondition for the necessary level of motivation and commitment.
2. Production of the quality and quantity of students trained in depth and breadth for the future knowledge-based economy is essential.
3. Sufficient capital funding is a pre-requisite.
4. Appropriate organizational design incorporating competing institutions and separation of powers at every level is required.
5. Diversity of economic strategy and not one focussed exclusively on one domain as the Soviet war machine focus illustrated.
6. Alliances with other countries and groups as the successful example of CERN showed as compared to the Soviet go-it alone model, is a precondition in a world of increasingly expensive technological projects.

These lessons need to be taken on board as we develop our own strategy for the future of Africa.